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(54) **REFLECTION-BASED LOCATION DETECTION**

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H04W 8/00	(2009.01)
H04W 52/02	(2009.01)
G01S 5/02	(2010.01)

(52) **U.S. Cl.**
CPC ***H04W 8/005*** (2013.01); ***G01S 5/0289*** (2013.01); ***H04W 52/0209*** (2013.01)

(58) **Field of Classification Search**
CPC H04W 84/18; H04W 88/06; H04W 76/02; H04W 8/245; H04W 24/02; H04W 88/04; H04W 16/26; H04M 1/7253; H04M 1/72522; H04M 2250/02
USPC 455/41.2, 11.1, 404.1, 404.2, 418–420, 455/456.1, 456.6, 507, 517
See application file for complete search history.

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(57) **ABSTRACT**

There is provided a system including a mobile device configured to transmit a first advertisement to a listening device and a repeater device, receive a data advertisement from the listening device in response to transmitting the first advertisement to the listening device, the data advertisement including a time difference between the listening device receiving the first advertisement and the listening device receiving a second advertisement transmitted from the repeater device in response to transmitting the first advertisement from the mobile device to the repeater device, and determine a location of the mobile device using the data advertisement including the time difference. In the system, the listening device and the repeater device may each include Bluetooth low energy devices.

20 Claims, 3 Drawing Sheets

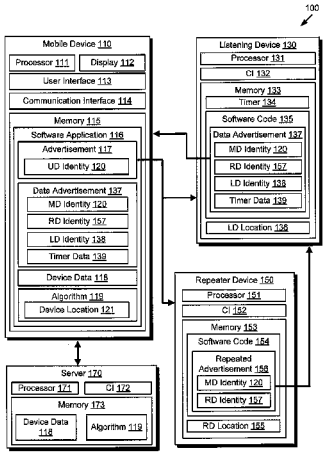

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Fig. 1

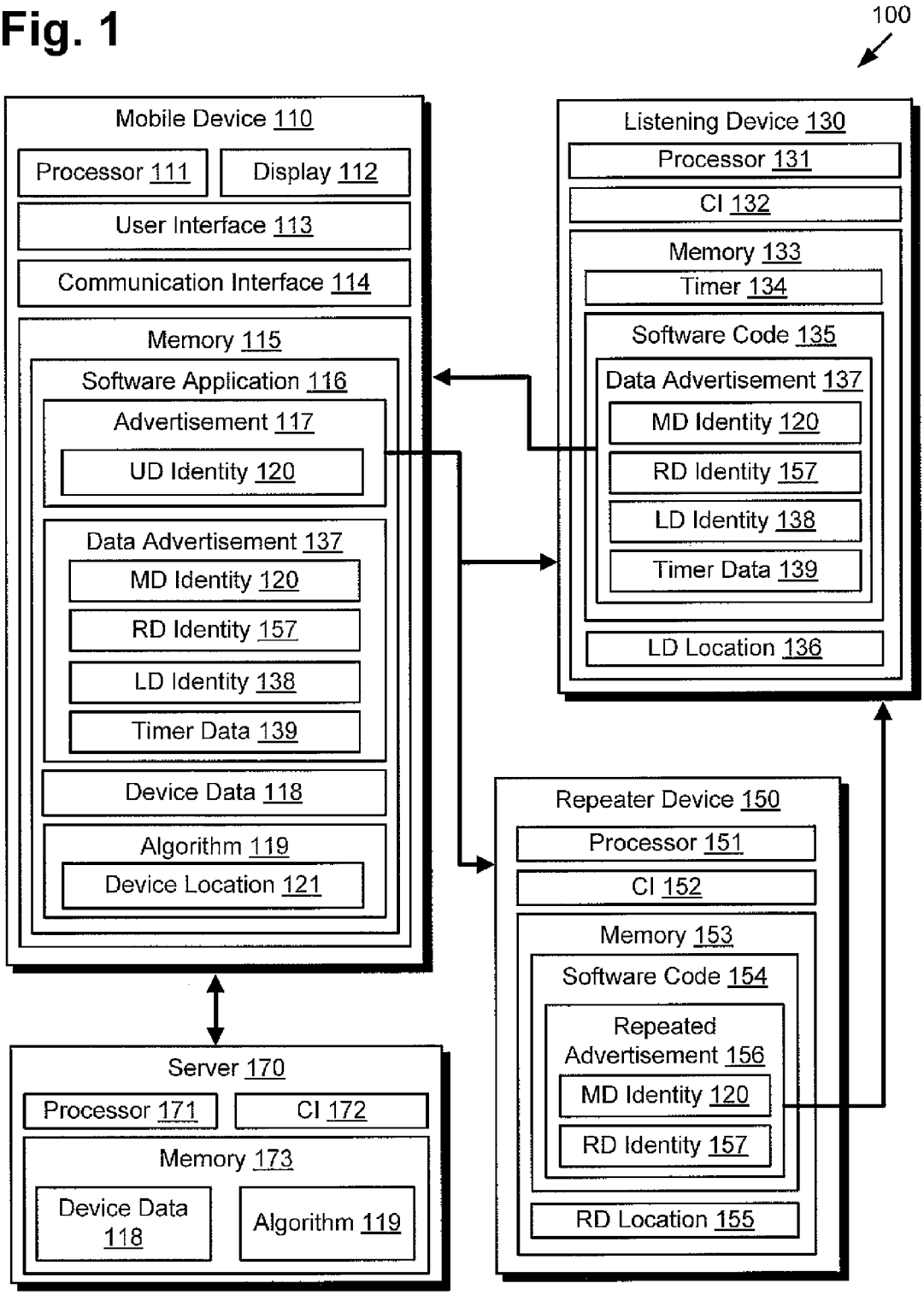

100
Mobile Device 110
Processor 111
Display 112
User Interface 113
Communication Interface 114
Memory 115
Software Application 116
Advertisement 117
UD Identity 120
Data Advertisement 137
MD Identity 120
RD Identity 157
LD Identity 138
Timer Data 139
Device Data 118
Algorithm 119
Device Location 121
Listening Device 130
Processor 131
CI 132
Memory 133
Timer 134
Software Code 135
Data Advertisement 137
MD Identity 120
RD Identity 157
LD Identity 138
Timer Data 139
LD Location 136
Repeater Device 150
Processor 151
CI 152
Memory 153
Software Code 154
Repeated Advertisement 156
MD Identity 120
RD Identity 157
RD Location 155
Server 170
Processor 171
CI 172
Memory 173
Device Data 118
Algorithm 119

Fig. 2

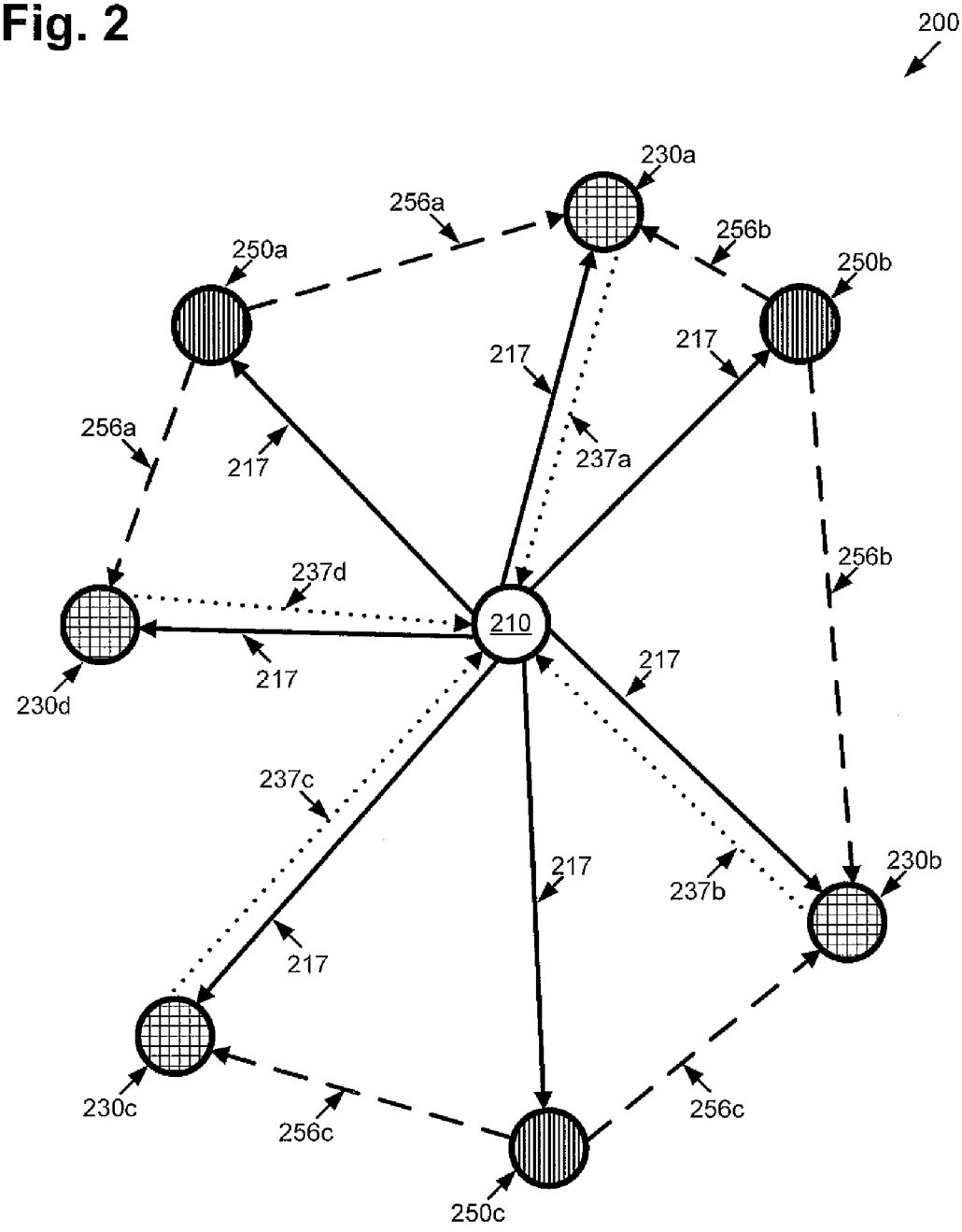
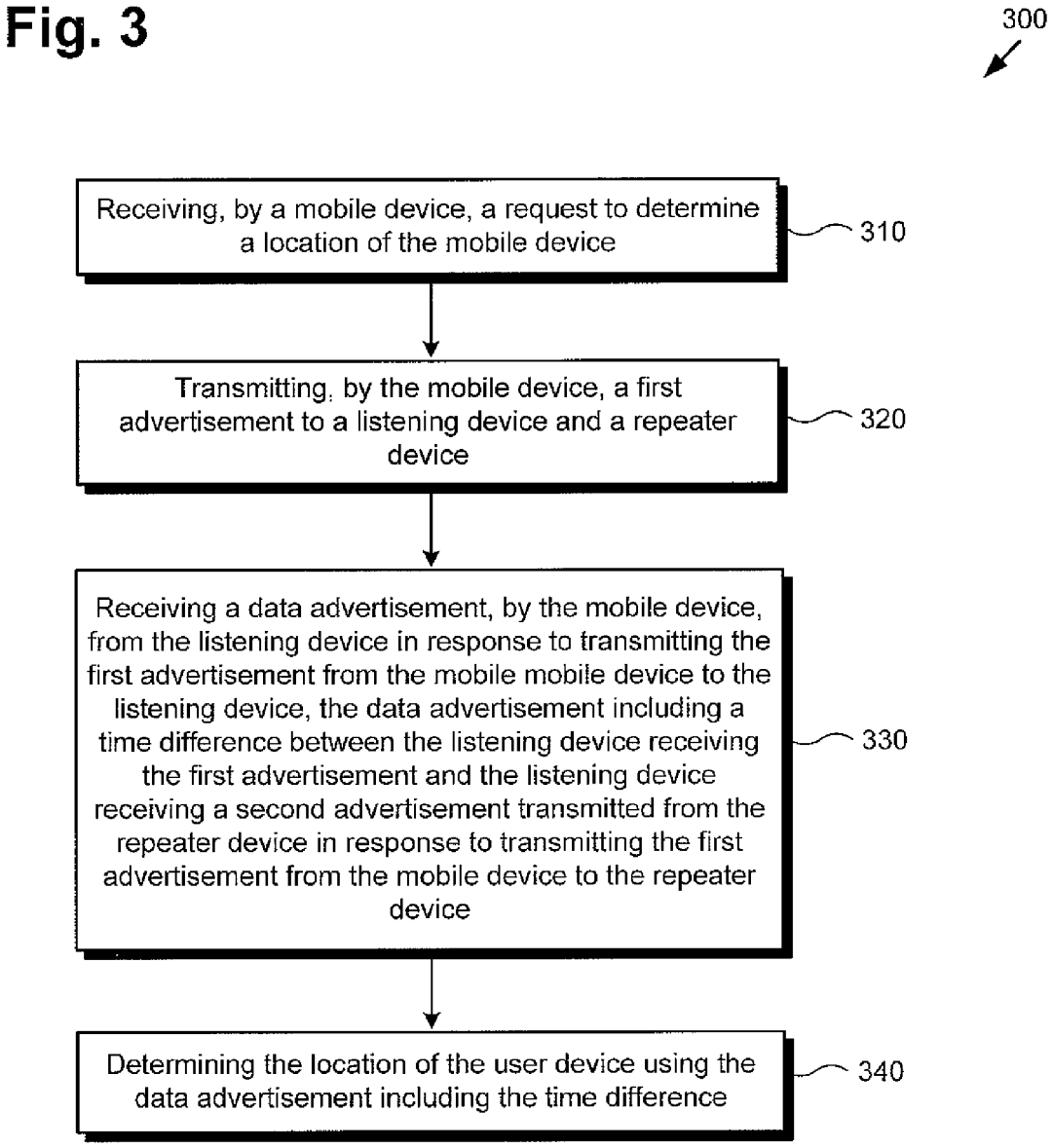

200
230a
256a
256b
250a
250b
217
217
256a
217
237a
256b
237d
210
230d
217
217
237c
217
237b
230b
217
230c
256c
256c
250c

Fig. 3


300
Receiving, by a mobile device, a request to determine a location of the mobile device
310
Transmitting, by the mobile device, a first advertisement to a listening device and a repeater device
320
Receiving a data advertisement, by the mobile device, from the listening device in response to transmitting the first advertisement from the mobile mobile device to the listening device, the data advertisement including a time difference between the listening device receiving the first advertisement and the listening device receiving a second advertisement transmitted from the repeater device in response to transmitting the first advertisement from the mobile device to the repeater device
330
Determining the location of the user device using the data advertisement including the time difference
340

REFLECTION-BASED LOCATION DETECTION

BACKGROUND

Nowadays, numerous software applications on mobile devices require tracking the location of the mobile devices to work properly. As such, different systems have been developed to accurately determine the location of a mobile device. For example, Global Positioning System (GPS), cell tower based tracking, and Wi-Fi based tracking are a few of the systems that have been developed in order to track the location of a mobile device, such as a mobile phone. However, many problems can occur with mobile devices that implement these current systems. For example, some of the current systems require a precision synchronization of time clocks between multiple stations that are used to determine the location of the mobile device. As such, even a small difference in the synchronization of the time clocks can mean significant errors when determining the location of the mobile device. As another example, the current systems require the mobile device to constantly transmit and listen for messages. This requires a lot of battery power to perform and as such drains the power supply of the mobile device.

SUMMARY

The present disclosure is directed to reflection-based location detection, substantially as shown in and/or described in connection with at least one of the figures, as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** presents a system for reflection-based location detection, according to one implementation of the present disclosure.

FIG. **2** presents an example of using multiple listening devices and repeater devices to determine a location of a mobile device using reflection-based location detection, according to one implementation of the present disclosure.

FIG. **3** shows a flowchart illustrating a method for reflection-based location detection, according to one implementation of the present disclosure.

DETAILED DESCRIPTION

The following description contains specific information pertaining to implementations in the present disclosure. The drawings in the present application and their accompanying detailed description are directed to merely exemplary implementations. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present application are generally not to scale, and are not intended to correspond to actual relative dimensions.

FIG. **1** presents a system for reflection-based location detection, according to one implementation of the present disclosure. System **100** of FIG. **1** includes mobile device **110**, listening device **130**, repeater device **150**, and server **170**. Mobile device **110** includes processor **111**, display **112**, user interface **113**, communication interface **114**, and memory **115**. Memory **115** includes software application **116**, which includes advertisement **117**, device data **118**, algorithm **119**, and data advertisement **137**. Advertisement **117** includes mobile device (MD) identity **120**. Algorithm **119** includes

device location **121**. Data advertisement **137** includes mobile device identity **120**, repeater device (RD) identity **157**, listening device (LD) identity **138**, and timer data **139**. Listening device **130** includes processor **131**, communication interface (CI) **132**, and memory **133**. Memory **133** includes timer **134**, software code **135**, and listening device location **136**. Software code **135** includes data advertisement **137**, which includes mobile device identity **120**, repeater device identity **157**, listening device identity **138**, and timer data **139**. Repeater device **150** includes processor **151**, communication interface **152**, and memory **153**. Memory **153** includes software code **154** and repeater device location **155**. Software code **154** includes repeater advertisement **156**, which includes mobile device identity **120** and repeater device identity **157**. Server **170** includes processor **171**, communication interface **172**, and memory **173**. Memory **173** includes device data **118** and algorithm **119**.

As illustrated in FIG. **1**, system **100** includes four separate devices in communication with one another, mobile device **110**, listening device **130**, repeater device **150**, and server **170**. Each of the devices of system **100** may include a personal computer, a mobile phone, a tablet, a wireless communication device, such as a Bluetooth low energy wireless device. For example, in one implementation, mobile device **110** includes a mobile phone, while listening device **130** and repeater device **150** each includes a Bluetooth low energy device. In such an example, mobile device **110**, listening device **130**, and repeater device **150** each communicate with each other using Bluetooth low energy wireless technology.

It should be noted that the implementation of FIG. **1** only illustrates one mobile device **110**, one listening device **130**, one repeater device **150**, and one server **170**, however, the present disclosure is not limited to the implementation of FIG. **1**. In other implementations, there can be multiple mobile devices, listening devices, repeater devices, and servers in communication with one another. For example, in one implementation, mobile device **110** may be in communication with more than one listening device **130** and more than one repeater device **150**.

As shown in FIG. **1**, mobile device **110** includes user interface **113** and display **112**. User interface **113** may comprise, for example, a keyboard, a mouse, a game controller, a touch-screen input, a thermal and/or electrical sensor, or any other device capable of accepting user input for use with mobile device **110**. Display **112** may comprise a liquid crystal display (LCD) screen built into mobile device **110**. In alternative implementations of the present disclosure, display **112** may be another type of display hardware, such as cathode-ray tubes (CRT) monitors. In yet other implementations, display **112** may also be touch sensitive and may serve as user interface **113**. Moreover, user interface **113** and display **112** may be externally attached to mobile device **110** through physical or wireless technology.

Also illustrated in FIG. **1**, mobile device **110** includes processor **111** and memory **115**. Processor **111** may be configured to access memory **115** to store received input or to execute commands, processes, or programs stored in memory **115**, such as software application **116**. Processor **111** may correspond to a processing device, such as a microprocessor or similar hardware processing device, or a plurality of hardware devices. Memory **115** is a sufficient memory capable of storing commands, processes, and programs for execution by processor **111**.

It should be noted that processor **131** and memory **133** of listening device **130**, processor **151** and memory **153** of repeater device **150**, and processor **171** and memory **173** of server **170** may be similar to processor **111** and memory **115**

of mobile device **110**. For example, processor **131** of listening device **130** may be configured to access memory **133** to store received input or to execute commands, processes, or programs stored in memory **133**. For a second example, processor **151** of repeater device **150** may be configured to access memory **153** to store received input or to execute commands, processes, or programs stored in memory **153**. Finally, for a third example, processor **171** of server **170** may be configured to access memory **173** to store received input or to execute commands, processes, or programs stored in memory **173**.

Also illustrated in FIG. **1**, mobile device **110** further includes communication interface **114**. In the implementation of FIG. **1**, communication interface **114** includes any device that is capable both transmitting data with a transmitter and receiving data with a receiver. Processor **111** of mobile device **110** is thus configured to control communication interface **114** to communicate with other electronic devices, such as listening device **130**, repeater device **150**, and server **170**. As such, communication interface **114** can utilize, for example, one or more of Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMax), ZigBee, Bluetooth, Bluetooth low energy, Code Division Multiple Access (CDMA), Evolution-Data Optimized (EV-DO), Global System for Mobile Communications (GSM), Long Term Evolution (LTE), and other types of wired and wireless technology.

It should be noted that communication interface **132** of listening device **130**, communication interface **152** of repeater device **150**, and communication interface **172** of server **170** are similar to communication interface **114** of mobile device **110**. For example, in one implementation, as discussed above, each of communication interface **114**, communication interface **132**, and communication interface **152** may be utilizing Bluetooth low energy wireless technology. In such an implementation, each of mobile device **110**, listening device **130**, and repeater device **150** may communicate with one another using Bluetooth low energy specifications.

Also illustrated in FIG. **1**, mobile device **110** includes software application **116**. In the implementation of FIG. **1**, mobile device **110** utilizes software application **116** to determine device location **121**, where device location **121** gives a location of mobile device **110**. As such, software application **116** may include source code automatically running on mobile device **110**, or launched by a user of mobile device **110**, that is used to determine device location **121** of mobile device **110**. Furthermore, software application **116** may have come preloaded on mobile device **110** or software application **116** may be downloaded and installed by a user of mobile device **110**.

Software application **116** determines device location **121** by first generating and transmitting advertisement **117**, where advertisement **117** corresponds to a data packet that includes the identity of mobile device **110**, such as mobile device identity **120**. For example, in one implementation, mobile device identity **120** includes the media access control (MAC) address of mobile device **110**. However, in other implementations, mobile device identity **120** can include any data that identifies mobile device **110**.

After generating advertisement **117**, as illustrated in the implementation of FIG. **1**, mobile device **110** utilizes software application **116** to transmit advertisement **117** to other devices, such as listening device **130** and repeater device **150**. For example, mobile device **110** may utilize software application **116** to generate advertisement **117**, where advertisement **117** includes mobile device identity **120**. Mobile device **110** then concurrently transmits advertisement **117** to both listening device **130** and repeater device **150**. For example, and as discussed above, in one implementation, listening device **130** and repeater device **150** may each include Bluetooth low energy devices. In such an implementation, mobile device **110** transmits advertisement **117** to each of listening device **130** and repeater device **150** using Bluetooth low energy wireless technology.

In one implementation, different advertisements generated and transmitted by mobile device **110** may include different device identities for mobile device **110**. For example, mobile device **110** may change device identity **120** each time mobile device **110** generates and transmits advertisement **117**. For another example, mobile device **110** may change device identity **120** for advertisement **117** at the expiration of a given time interval. By using a different device identity **120** when mobile device **110** generates and transmits advertisement **117**, mobile device **110** cannot be tracked over time by other devices.

Continuing with the implementation of FIG. **1**, in response to repeater device **150** and listening device **130** receiving advertisement **117** from mobile device **110**, repeater device **150** both generates and transmits repeated advertisement **156** using software code **154**, while listening device starts timer **134** using software code **135**. Each of software code **135** and software code **154** corresponds to source code running on listening device **130** and repeater device **154**, respectively. As such, listening device **130** and repeater device **150** respectively utilize software code **135** and software code **154** to perform the functions described below by each of listening device **130** and repeater device **150**.

Repeater device **150** first generates and transmits repeated advertisement **156** utilizing software code **154**. Repeater device **150** generates repeated advertisement **156** by taking advertisement **117** received from mobile device **110** and adding repeater device identity **156**, where repeater device identity **156** corresponds to data that includes the identity of repeater device **150**. After generating repeated advertisement **156**, repeater device **150** transmits repeated advertisement **156** to other devices, such as listening device **130**. For example, and using the implementation discussed above where listening device **130** and repeater device **150** each include Bluetooth low energy devices, repeater device **150** transmits repeater advertisement **154** to listening device **130** using Bluetooth low energy wireless technology.

Timer **134** corresponds to a timing device that listening device **130** utilizes to measure a time difference between when listening device **130** receives an original advertisement from a mobile device and when listening device **130** receives a repeated advertisement from a repeater device, where the repeated advertisement corresponds to the original advertisement. For example, in the implementation of FIG. **1**, in response to listening device **130** receiving advertisement **117** from mobile device **110**, listening device **130** begins timer **134**. After beginning timer **134**, listening device **130** waits to receive repeated advertisement **156** from repeater device **150** and records how much time passed between receiving advertisement **117** from mobile device **110** and receiving repeated advertisement **156** from repeater device **150**.

After listening device **130** records the time difference between receiving advertisement **117** and repeated advertisement **156**, listening device **130** utilizes software code **135** to generate and transmit data advertisement **137**. Data advertisement **137** corresponds to a data packet that includes mobile device identity **120**, repeater device identity **156**, listening device identity **138**, and timer data **139**. As discussed above, mobile device identity **120** corresponds to data that includes the identity of mobile device **110** and repeater device identity **156** corresponds to data that includes the identity of repeater

device **150**. Furthermore, listening device identity **138** corresponds to data that includes the identity of listening device **130**. Timer data **139** corresponds to data that includes the time difference recordings measured by listening device **130**, where, as discussed above, a time difference recording measures the time it takes between listening device **130** receiving advertisement **117** from mobile device **110** and listening device **130** receiving repeated advertisement **156** from repeater device **150**.

It should be noted that the implementation of FIG. **1** only illustrates listening device **130** receiving one advertisement **117** from mobile device **110** and one repeated advertisement **156** from repeater device **150**; however, the present disclosure is not limited to the implementation of FIG. **1**. For example, in one implementation, listening device **130** may receive multiple advertisements from mobile device **110** and multiple repeated advertisements from repeater device **150**, where each of the repeated advertisements corresponds to one of the advertisements. As another example, in a second implementation, listening device **130** may receive one advertisement **117** from mobile device **110** and multiple repeated advertisements from more than one repeater device, where each of the multiple repeated advertisements corresponds to advertisement **117**. Finally, for a third example, in third implementation, listening device **130** may receive multiple advertisements from mobile device **110** and multiple repeated advertisements from more than one repeater device, where each of the multiple repeated advertisements corresponds to one of the multiple advertisements received from mobile device **110**. In each implementation, listening device **130** would record a time difference for each instance of receiving an advertisement **117** from mobile device **110** and receiving a corresponding repeated advertisement **156** from a repeater device **150** in timer data **139**.

Also illustrated in implementation of FIG. **1**, after listening device **130** generates data advertisement **137**, listening device **130** transmits data advertisement **137** to mobile device **110**. For example, and using the implementation discussed above where listening device **130** and repeater device **150** each include a Bluetooth low energy device, listening device **130** transmits data advertisement **137** to mobile device **110** using Bluetooth low energy wireless technology.

As further illustrated in the implementation of FIG. **1**, after receiving data advertisement **137** from listening device **130**, mobile device **110** utilizes device data **118** and algorithm **119** to calculate device location **121** based on data advertisement **137**. Device data **118** includes data corresponding to both listening devices and repeater devices, such as listening device **130** and repeater device **150**. The data in device data **118** can include, but is not limited to, the identity and location of listening devices and repeater devices. For example, in the implementation of FIG. **1**, device data **118** would include listening device identity **138** and listening device location **136** for listening device **130**, and repeater device identity **156** and repeater device location **155** for listening device **150**, where listening device location **136** and repeater device location **155** correspond respectively to the locations of listening device **130** and repeater device **150**. Mobile device **110** can thus use device data **118** to determine listening device location **136** and repeater device location **155** based on listening device identity **138** and repeater device identity **156** from data advertisement **137**.

Algorithm **119** calculates device location **121** based on data advertisement **137** using device data **118**. To calculate device location **121**, algorithm **119** uses time data **138** from data advertisement **137** and the locations of listening device **130** and repeater device **150** from device data **118** to triangulate device location **121**. For example, in one implementation, algorithm **119** uses Time Difference of Arrival techniques to determine device location **121** based on data advertisement **137**.

It should be noted that the implementation of FIG. **1** further includes server **170** in communication with mobile device **110**. In implementations where system **100** includes server **170**, server **170** may be utilized by mobile device **110** to determine device location **121**. For example, in one implementation, mobile device **110** may not include device data **118** and algorithm **119**. In such an implementation, mobile device **110** may transmit data advertisement **137** to server **170** and server **170** may utilize data advertisement **137**, device data **118**, and algorithm **119** to determine device location **121** in a similar way as mobile device **110** determined device location **121** described above. Server **170** may then transmit device location **121** to mobile device **110**. For another example, in one implementation, mobile device **110** may only include algorithm **119**, but not device data **118**. In such an implementation, server **170** transmits device data **118** to mobile device **110** so that mobile device **110** can calculate device location **121**.

As discussed above, in one implementation, each of listening device **130** and repeater device **150** may include Bluetooth low energy devices. In such an implementation, mobile device **110**, listening device **130**, and repeater device **150** transmit advertisements using Bluetooth low energy specifications. As such, mobile device **110** transmits advertisement **117** on different frequency channels using a given time interval between each frequency channel. For example, mobile device **110** transmits advertisement **117** using three different frequency channels with a 10 mS time interval delay between transmissions on each of the three frequency channels. Mobile device **110** may then repeat the transmission on the three frequency channels using a 20 mS delay after the transmission on the last frequency channel. Furthermore, each of listening device **130** and repeater device **150** may be configured to listen to one of the three frequency channels for receiving advertisement **117** from mobile device **110**.

Furthermore, one or more of mobile device **110**, listening device **130**, or repeater device **150** may add a signature to transmissions for security purposes. For example, either mobile device **110** may add a cryptographic hash to advertisement **117** when generating advertisement **117**, or repeater device **150** may add a cryptograph hash to repeated advertisement **156** when generating repeated advertisement **156**. In such an example, server **170** would also include data corresponding to the cryptographic hash.

FIG. **2** presents an example of using multiple listening devices and repeater devices to determine a location of a mobile device using reflection-based location detection, according to one implementation of the present disclosure. System **200** of FIG. **2** includes mobile device **210**, listening device **230***a*, listening device **230***b*, listening device **230***c*, and listening device **230***d*, collectively referred to as listening devices **230***a-d*, and repeater device **250***a*, repeater device **250***b*, and repeater device **250***c*, collectively referred to as repeater devices **250***a-c*. System **200** further includes advertisement **217**, data advertisement **237***a*, data advertisement **237***b*, data advertisement **237***c*, and data advertisement **235***d*, collectively referred to as data advertisements **237***a-d*, and repeated advertisement **256***a*, repeated advertisement **256***b*, repeated advertisement **256***c*, and repeated advertisement **254***d*, collectively referred to as repeated advertisements **256***a-c*.

With reference to FIG. **2**, mobile device **210** and advertisement **217** correspond respectively to mobile device **110** and

advertisement **217** from FIG. **1**. Each one of listening devices **230***a-d*, repeater devices **250***a-c*, data advertisements **237***a-d*, and repeated advertisements **256***a-c* from FIG. **2** corresponds respectively to listening device **130**, repeater device **150**, data advertisement **137**, and repeated advertisement **156** from FIG. **1**.

As illustrated in the implementation of FIG. **2**, mobile device **210** transmits advertisement **217** (represented in FIG. **2** by the solid arrows) to listening devices **230***a-d* and repeater devices **250***a-c*. For example, and as discussed above in one implementation, each of listening devices **230***a-d* and repeater devices **250***a-c* include Bluetooth low energy devices. In such an implementation, mobile device **210** may transmit advertisement **217** to listening devices **230***a-d* and repeater devices **250***a-c* using Bluetooth low energy wireless technology.

Also illustrated in the implementation of FIG. **2**, repeater devices **250***a-c* transmit repeated advertisements **256***a-c* (represented in FIG. **2** by the dashed arrows) to listening devices **230***a-d*. For example, and as discussed in regards to FIG. **1**, in response to listening devices **250***a-c* receiving advertisement **217** from mobile device **210**, repeater devices **250***a-c* generate repeated advertisements **256***a-c* using advertisement **217** and adding a repeater device identity. After generating repeated advertisements **256***a-c*, listening devices **250***a-c* transmit repeated advertisements **256***a-c* to listening devices **230***a-d*. For example, and using the implementation above where each of listening devices **230***a-d* and repeater devices **250***a-c* include Bluetooth low energy devices, repeater devices **250***a-c* transmit repeated advertisements **256***a-c* to listening devices **230***a-d* using Bluetooth low energy wireless technology.

For example, and as illustrated in FIG. **2**, repeater device **250***a* generates repeater advertisement **256***a* by adding repeater device identity of repeater device **250***a* to advertisement **217**. Repeater device **250***a* then transmits repeater advertisement **256***a* to each of listening device **230***a* and listening device **230***d*. For a second example, repeater device **250***b* generates repeater advertisement **256***b* by adding repeater device identity of repeater device **250***b* to advertisement **217**. Repeater device **250***b* then transmits repeater advertisement **256***b* to each of listening device **230***a* and listening device **230***b*. Finally, for a third example, repeater device **250***c* generates repeater advertisement **256***c* by adding repeater device identity of repeater device **250***c* to advertisement **217**. Repeater device **250***c* then transmits repeater advertisement **256***c* to each of listening device **230***b* and listening device **230***c*.

Also illustrated in the implementation of FIG. **2**, listening devices **230***a-d* transmit data advertisements **237***a-d* (represented in FIG. **2** as dotted arrows) to mobile device **210**. For example, and as discussed above with regards to FIG. **1**, in response to listening devices **237***a-d* receiving advertisement **217** from mobile device **210**, listening devices **237***a-d* start a timer to time how long it takes for listening devices **237***a-d* to receive repeated advertisements that correspond to advertisement **217** from repeater devices, such as receiving repeated advertisements **256***a-c* from repeater devices **250***a-c*. Listening devices **230***a-d* then record the time difference between receiving advertisement **217** from mobile device **210** and receiving repeated advertisements **256***a-c* from repeater device **250***a-c* in data advertisements **237***a-d*. Also, listening devices **230***a-d* transmit data advertisements **237***a-d* to mobile device **210**. For example, and using the implementation above where each of listening devices **230***a-d* and repeater devices **250***a-c* include Bluetooth low energy devices, listening devices **230***a-d* transmit data advertisements **237***a-d* to mobile device **210** using Bluetooth low energy wireless technology.

For example, and as illustrated in FIG. **2**, data advertisement **237***a* would include data describing time differences of arrival between listening device **230***a* receiving advertisement **217** from mobile device **210** and receiving each of repeated advertisement **256***a* and repeated advertisement **256***b* from repeater device **250***a* and repeater device **250***b*, respectively. Data advertisement **237***b* would include data describing time differences of arrival between listening device **230***b* receiving advertisement **217** from mobile device **210** and receiving each of repeated advertisement **256***b* and repeated advertisement **256***c* from repeater device **250***b* and repeater device **250***c*, respectively. Data advertisement **237***c* would include data describing a time difference of arrival between listening device **230***c* receiving advertisement **217** from mobile device **210** and receiving repeated advertisement **256***c* from repeater device **250***c*. Finally, data advertisement **235***d* would include data describing a time difference of arrival between listening device **230***d* receiving advertisement **217** from mobile device **210** and receiving repeated advertisement **256***a* and repeater device **250***a*.

FIG. **3** shows a flowchart illustrating a method for reflection-based location detection, according to one implementation of the present disclosure. The approach and technique indicated by flowchart **300** are sufficient to describe at least one implementation of the present disclosure, however, other implementations of the disclosure may utilize approaches and techniques different from those shown in flowchart **300**. Furthermore, while flowchart **300** is described with respect to FIG. **1**, the disclosed inventive concepts are not intended to be limited by specific features shown and described with respect to FIG. **1**. Furthermore, with respect to the method illustrated in FIG. **3**, it is noted that certain details and features have been left out of flowchart **300** in order not to obscure the discussion of inventive features in the present application.

Referring now to flowchart **300** of FIG. **3**, flowchart **300** includes receiving, by a mobile device, a request to determine a location of the mobile device (**310**). For example, processor **111** of mobile device **110** may execute software application **116** to receive a request to determine device location **121**. The request may be received by a user of mobile device **110** using user interface **113**, or the request may be received by an application or program running on mobile device **110**. As discussed above, device location **121** corresponds to a location of mobile device **110**.

Flowchart **300** also includes transmitting, by the mobile device, a first advertisement to a listening device and a repeater device (**320**). For example, processor **111** of mobile device **110** may execute software application **116** to transmit advertisement **117** to listening device **130** and repeater device **150**. As discussed above, mobile device **110** transmits advertisement **117** to listening device **130** and repeater device **150** concurrently, where advertisement **117** includes mobile device identity **120**. Mobile device identity **120** corresponds to data that includes the identity of mobile device **110**. Furthermore, in the implementation, where listening device **130** and repeater device **150** each include Bluetooth low energy devices, mobile device **110** transmits advertisement **117** to listening device **130** and repeater device **150** using Bluetooth low energy wireless technology.

Flowchart **300** also includes receiving a data advertisement, by the mobile device, from the listening device in response to transmitting the first advertisement from the mobile device to the listening device, the data advertisement including a time difference between the listening device

receiving the first advertisement and the listening device receiving a second advertisement transmitted from the repeater device in response to transmitting the first advertisement from the mobile device to the repeater device (**330**).

For example, processor **111** of mobile device **110** may execute software application **116** to receive data advertisement **137** from listening device **130** in response to transmitting advertisement **117** from user device **110** to listening device **130**. As discussed above, listening device **130** generates data advertisement **137** to include timer data **139**, where timer data **139** corresponds to data that includes a time difference of arrival between listening device **130** receiving advertisement **117** from mobile device **110** and listening device **130** receiving repeated advertisement **156** from repeater device **150**. Repeater device **150** transmits repeated advertisement **156** to listening device **130** in response to repeater device **150** receiving advertisement **117** from user device **110**. In the implementation, as discussed above where listening device **130** and repeater device **150** include Bluetooth low energy devices, mobile device **110** may receive data advertisement **137** from listening device **130** using Bluetooth low energy wireless technology.

Flowchart **300** also includes determining the location of the mobile device using the data advertisement including the time difference (**340**). For example, processor **111** of mobile device **110** may execute software application **116** to determine device location **121** using data advertisement **137** including timer data **139**. As discussed above, in one implementation, processor **111** of mobile device **110** determines device location **121** using algorithm **119** based on data advertisement **137** including timer data **139** and device data **118**, where device data **118** includes, but is not limited to, listening device identity **138** and listening device location **136** of listening device **130**, and repeater device identity **156** and repeater device location **155** of repeater device **150**. Algorithm **119** can thus calculate device location **121** using listening device location **136**, repeater device location **156**, and timer data **139** from data advertisement **137** to triangulate device location **121**.

In another implementation, processor **111** of mobile device **110** may execute software application **116** to determine device location **121** by transmitting data advertisement **137** including timer data **139** to server **150**. Server **150** may then calculate device location **121** in a similar way as mobile device **110** calculated device location **121** discussed above. Finally, processor **111** of mobile device **110** may execute software application **116** to receive device location **121** from server **170**.

From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described above, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

What is claimed is:

1. A mobile device comprising:

a memory storing a software code; and

a processor configured to execute the software code to:

transmit a first advertisement to a listening device and a repeater device;

receive a data advertisement from the listening device in response to transmitting the first advertisement from the mobile device to the listening device, the data advertisement including a time difference between the listening device receiving the first advertisement and the listening device receiving a second advertisement transmitted from the repeater device in response to transmitting the first advertisement from the mobile device to the repeater device; and

determine a location of the mobile device using the data advertisement including the time difference.

2. The mobile device of claim **1**, wherein transmitting the first advertisement includes transmitting the first advertisement using Bluetooth low energy.

3. The mobile device of claim **1**, wherein the listening device and the repeater device each include Bluetooth low energy devices.

4. The mobile device of claim **1**, wherein determining the location includes transmitting the data advertisement including the time difference to a server and receiving the location from the server.

5. The mobile device of claim **1**, wherein determining the location includes calculating the location using an algorithm based on the data advertisement including the time difference.

6. The mobile device of claim **1**, wherein the data advertisement further includes an identity of the listening device and an identity of the repeater device.

7. The mobile device of claim **1**, wherein the processor is further configured to execute the software code to:

transmit the first advertisement to a plurality of listening devices including the listening device and a plurality of repeater devices including the repeater device;

receive a plurality of data advertisements each from one of the plurality of listening devices; and

determine the location using the plurality of data advertisements.

8. A listening device comprising:

a memory storing a software code; and

a processor configured to execute the software code to:

receive a first advertisement from a mobile device;

receive a second advertisement from a repeater device in response to the repeater device receiving the first advertisement from the mobile device;

generate a data advertisement, the data advertisement including a time difference between the listening device receiving the first advertisement from the mobile device and the listening device receiving the second advertisement from the repeater device; and

transmit the data advertisement including the time difference to the mobile device to facilitate determining a location of the mobile device by the mobile device using the data advertisement including the time difference.

9. The listening device of claim **8**, wherein the first advertisement and the second advertisement are received using Bluetooth low energy and the data advertisement is transmitted using the Bluetooth low energy.

10. The listening device of claim **8**, wherein the listening device and the repeater device each include Bluetooth low energy devices.

11. The listening device of claim **8**, wherein to determine the location of the mobile device, the mobile device transmits the data advertisement including the time difference to a server and receives the location from the server.

12. The listening device of claim 8, wherein to determine the location of the mobile device, the mobile device calculates the location using an algorithm based on the data advertisement including the time difference.

13. The listening device of claim 8, wherein the data advertisement further includes an identity of the listening device and an identity of the repeater device.

14. A method for determining a location of a mobile device, the method comprising:

transmitting, by the mobile device, a first advertisement to a listening device and a repeater device;

receiving a data advertisement, by the mobile device, from the listening device in response to transmitting the first advertisement to the listening device, the data advertisement including a time difference between the listening device receiving the first advertisement and the listening device receiving a second advertisement transmitted from the repeater device in response to transmitting the first advertisement from the mobile device to the repeater device; and

determining the location of the mobile device using the data advertisement including the time difference.

15. The method of claim 14, wherein transmitting the first advertisement by the mobile device includes transmitting the first advertisement using Bluetooth low energy.

16. The method of claim 14, wherein the listening device and the repeater device each include Bluetooth low energy devices.

17. The method of claim 14, wherein to determine the location of the mobile device, the method comprises:

transmitting, by the mobile device, the data advertisement including the time difference to a server; and

receiving, by the mobile device, the location from the server.

18. The method of claim 14, wherein to determine the location of the mobile device, the method comprises:

calculating, by the mobile device, the location using an algorithm based on the data advertisement including the time difference.

19. The method of claim 14, wherein the data advertisement further includes an identity of the listening device and an identity of the repeater device.

20. The method of claim 14 further comprising:

transmitting the first advertisement to a plurality of listening devices including the listening device and a plurality of repeater devices including the repeater device;

receiving a plurality of data advertisements each from the plurality of listening devices; and

determining the location using the plurality of data advertisements.

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